Newsletter November 2020

Dear participants of CoolFish,

We are approaching Christmas at fast speed and here is a summary of what we have done recently in CoolFish and what we plan to continue with.

Workshops

We have had two workshops this autumn. The first was an online meeting during International cold chain conference. This table gives an overview of the presentations:

The project CoolFish	Kristina N. Widell (SINTEF Ocean)
Energy efficiency in fish processing	Tom Ståle Nordtvedt (SINTEF Ocean)
Natural refrigerants	Trygve Eikevik (NTNU)
Utilization of cold from LNG	Muhammad Zahid Saeed (NTNU)
Cold Chain Technology Brief on fishing vessel application	Didier Coulomb (IIR)
Further work and other projects	Kristina N. Widell (SINTEF Ocean) and Alex C. Pachai (Johnson Controls)

The second workshop was also held online, and it was open to participants both within the project and others. This was the presentations:

Welcome and introduction	Kristina N. Widell (SINTEF Ocean)
Experiences and some results from measurements onboard	Eirik S. Svendsen (SINTEF Ocean)
Possibilities of utilizing cold from LNG onboard	Muhammad Zahid Saeed (NTNU)
Design and status of CO_2 system for MMC	Ignat Tolstorebrov (NTNU)
CO_2 Compressors	Engin Söylemez (NTNU)
Onboard CO_2 plate freezing with cold thermal energy storage	Espen Verpe (SINTEF Energi)
Alternative fuels and propulsion systems for fishing vessels	Cecilia Gabrielii (SINTEF Energi)
Carbon footprint of fisheries	Sepideh Jafarzadeh (SINTEF Ocean)
Existing projects and new applications/collaborations	Guro M. Tveit, Tom Ståle Nordtvedt (SINTEF Ocean)
Further activities and closure	Kristina N. Widell (SINTEF Ocean)

The presentations from both workshops are available on the webpage of CoolFish: www.sintef.no/en/projects/coolfish

We will conduct one or more workshops next year also, probably starting with an online meeting in the spring. Hopefully, we will be able to meet again later that year!

New project partners

Bluewild AS would like to be a partner in CoolFish. They are planning a new fishing vessel, which will have the possibility of different types of fishing and processing onboard and PTG are already involved in this work. They wish to join CoolFish to be able to develop systems for processing of rest raw materials (e.g. heads, viscera, bones, skin). When the existing partners of Coolfish have accepted the new partner, they will be involved in the project and more specifically in a new industry case. Possibilities of an innovation project (IPN) as spin-off will also be evaluated. The deadline for this is in April 2021.

Industry cases

We are well into the work in three of four industry cases:

Case 1: Energy efficient RSW units – measurements onboard

Refrigeration equipment vendor Øyangen has installed measurement instruments in the fishing vessel Selvåg Senior, which are logging temperature, water flow and energy use. The logged data together with information on catch are being used for analysing operational profiles under different situations. In addition, this may be used for finding ways of increasing energy efficiency, both in this vessel and in other vessels.

A research cruise with the combined purse seine/pelagic trawler Selvåg Senior was conducted 28.09 to 06.10. The main objective was to collect data from the onboard energy systems, with a purpose to gain knowledge on energy demands during the different stages of fishing. To do so the following tasks were done:

- Instrumentation in RSW tank on board (BB2). HOBO loggers were used to log both horizontally (one rope) and vertically (one rope).
- Logging of fuel was done manually from an onboard system.
- Energy measurements of the refrigeration systems. PLC controlling the system and live view of measurements. Temperature loggers were calibrated.
- Catch log for operations, times and relevant data, weather data, size of catch etc.
- Temperature logging of mackerel during unloading (n=15).
- Established a timeline from the beginning to the end. Showing the different stages: steaming to fishing ground, searching for fish, fishing operation, return to harbor.

The period covered two fishing trips, both to fishing grounds south-southeast of Shetland isles. The boat was fishing for mackerel during both cruises. The gathered data provides opportunity to analyze the energy efficiency of the refrigeration systems, and knowing the fuel consumption, covered distance and size of catch, also efficiency of the overall fishing operation.

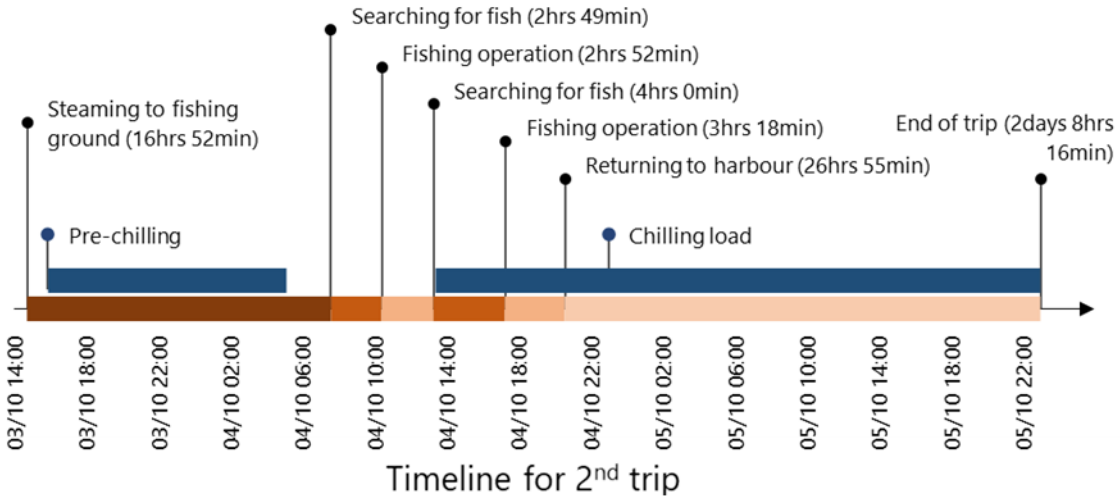

Figure 1: Example of a timeline with primary events

Instrumentation of logger within one of the RSW tanks was done to reveal possible temperature gradients within the tank. Ropes with loggers were attached in horizontal and vertical direction to analyze this.

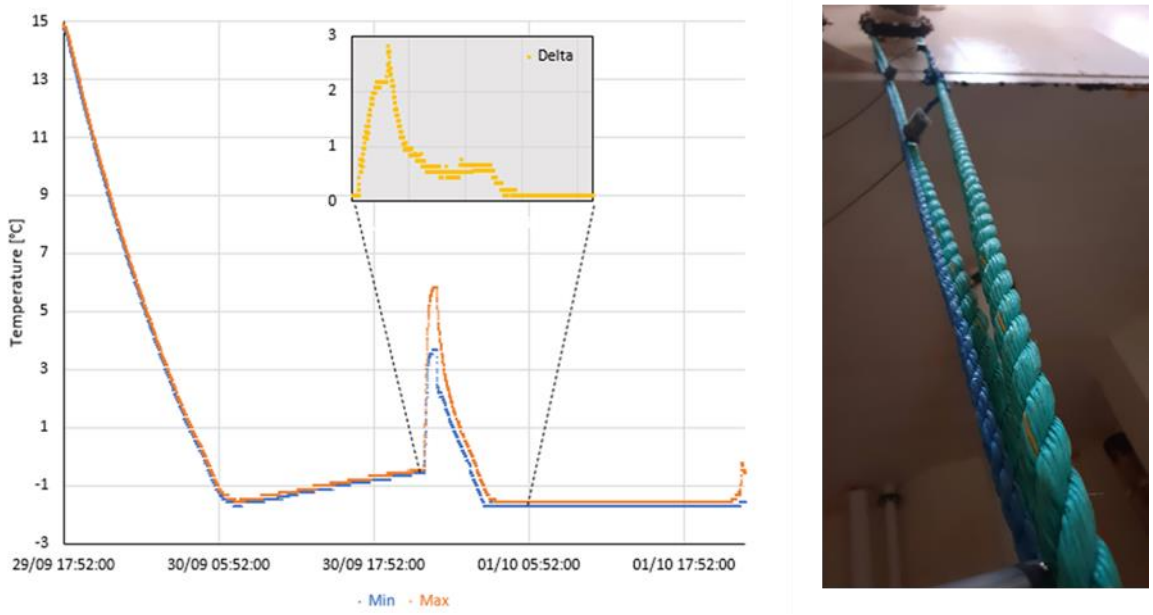

Figure 2: Example of data from temperature loggers within one of the RSW tanks, together with a picture of the vertical rope arrangement

The process of analysing the quite large dataset retrieved from this cruise is currently ongoing, and it is planned to conduct a number of energy calculations to paint a picture of the baseline energy efficiency onboard. The results will be used as valuable input for design of energy efficiency technology, proposal of operational patterns and used as scenario for modelling and simulation. This will be presented in a cruise report and also a conference paper which will be submitted to *Ammonia and CO2 refrigeration Technologies conference 2021*.

Case 2: Design concepts for cold utilization from LNG driven ships

This year, master student Muhammad Zahid Saeed delivered his master thesis, and he continued working with the topics during the summer. In the master thesis, he analysed different concepts of integrating LNG cold with chilling and freezing systems. LNG cold can be used as a sub-cooler in the refrigeration system, chilling of RSW tank, thermal storage, air conditioning, and combination of these applications. The outcome is an energy efficient thermal system. Numerical investigations were also performed for heat recovery to process rest raw material (RRM), integration of water/ice and dry ice (CO2) energy storage, and two-phase ejector for CO2 thermal storage. During the summer job, design modifications were introduced in chilling tanks for built-in and add-in thermal storage. Besides, ice handling and generation mechanisms were evaluated for small and large fishing boats.

In September, Zahid started a Ph.D. in the CruiZe project. Modern ships expect to use alternative propulsion systems (hydrogen fuel cells, battery, hybrid, LNG, etc.), which will affect the onboard thermal systems. Innovative solutions are crucial to fulfil energy demands and meet the zero-emission target. The main task of the Ph.D. is to develop and validate dynamic models for energy efficiency in advanced passenger ships.

The best system solutions from this work will be used in further modelling and discussed with relevant partners.

Case 3: Develop concepts for thermal energy systems on hybrid/electric driven ships

This industry case has not started yet but can be a case on utilizing excess heat or cold for processing of rest raw material onboard. Possible partners: Bluewild, PTG, NTNU, SINTEF Ocean.

Case 4: Design concepts for *integrated thermal energy units*, for cooling and heating

MMC has bought components for a refrigeration system with CO_2, which will be set up with the help of NTNU. The system will be used for gaining experience and measuring different operational situations. The system will have three compressors with flexible attachment to different pressure levels, depending on refrigeration demand for AC, RSW and freezing. The system will also accumulate hot water for processes and room heating. Cold recovery from melting of "return-ice" will also be included. Danfoss will contribute with their competence of regulating systems. Different ejector systems will be implemented to demonstrate benefits of active expansion work recovery.

Postdoc and master student

Engin Söylemez is since August part of the team at Energy and Process Engineering Department at NTNU as postdoctoral fellow. He got his PhD degree from Marmara University in Turkey and he has been working in HVAC sector, particularly refrigeration sector, for more than 10 years. He worked previously at R&D Center for Refrigeration at Bosch BSH Turkey as cooling lead. Engin will perform the tasks from NTNU mainly within the work packages *energy efficiency* and partly the *industrial cases*. He will also support the Master students of CoolFish during their project work and master thesis.

Pavel Semaev is our new project/master student in CoolFish. He is since 2019 a student attending the MSc Sustainable energy program at NTNU Trondheim. He follows the specialization in Sustainable Heat Pumping Processes and Systems. He has a bachelor's degree in Mechanical Engineering from HVL Bergen.

The goal of the project work is to follow up on an implementation of a CO_2 refrigeration system at MCC First Process. This unit will be applied to test CO_2 components developed and applied by MCC. Developing simulation models for the CO_2 unit will be an important part of this project, and the data will be validated when the first performance data are available from the commissioning phase in 2021. The developed system will be a test site in terms of system performance, energy efficiency, and applicability for future installation at fishing vessels.

Reports and publications

We have finalised two reports from the project: "Alternative Fuels and Propulsion Systems for Fishing vessels" and "Carbon Footprint of Fisheries – a review of standards methods and tools" which are now both available on the project website https://www.sintef.no/en/projects/coolfish/.

Muhammad Zahid Saeed has submitted a paper to the Gustav Lorenzen conference, which will be held online in December. It is organized by Japan Society of Refrigerating and Airconditioning Engineers (JSRAE) together with International Institute of Refrigeration (IIR). The title of the paper is "Integrated thermal storage and heat recovery of the CO_2 refrigeration system for fishing vessels". He also presented a paper to the International cold chain conference (ICCC), with the title "Cryogenic cold utilization and system integration possibilities for LNG-driven fishing vessels". Co-authors were project participants from SINTEF Ocean and NTNU. The ICCC was supposed to take place in Nantes in April but was postponed to August. The conference was partly online and several from SINTEF and NTNU participated. Tom Ståle Nordtvedt had a keynote presentation in this conference, with the title "Refrigeration and sustainability in the seafood cold chain".

CO_2 Compressors

NTNU has started on a presentation on the latest CO_2 Compressor technology (semi hermetic type of compressors). It was presented during the workshop in October, and is available on the webpage (www.sintef.no/en/projects/coolfish/). It will be updated with more information continuously (next version will also include open type compressors).

An overview of max capacities:

Brand	Type	Mass flow [m³/h]	Max pressure [bar]	Max cooling capacity [kW]
Dorin	*Transcritical*	82	110	400
	Subcritical	99	60	350
GEA	*Transcritical*	38.2	130	180
	Subcritical	49	51	180
Bitzer	*Transcritical*	99.2	130	180
	Subcritical	55	23	180

The new largest capacity compressors:

- Dorin will present new CO_2 compressors platform based on a 6 cylinders design and 98.5 m^3/h with utmost efficiency levels.
- Bitzer has shown the new CKHE7, 140 hp compressor with 8 cylinders and 99.2 m^3/h.

Here are some pictures of compressors:

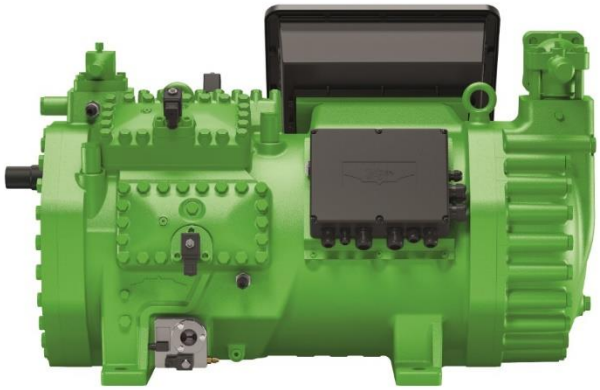

Figure 3 Picture of the new CO2 compressor from Bitzer (CKHE7).

Figure 4 Picture of the new CO2 compressor from Dorin (CD600). (https://www.youtube.com/watch?v=UqpPMYSKzR8)

Figure 5 Picture of the largest CO_2 compressor from Bock (larger versions are under development)

Maritime Refrigeration Technology Hub

We have started to discuss the layout and content of the *Maritime Refrigeration Technology Hub.* This R&D hub will be a web-based platform that enables information and knowledge exchange, as well as facilitates collaboration between industry and research institutions, both in Norway and internationally. In the first phase, the platform will be primarily aimed at stakeholders in the fishing vessel sector but may be expanded to include several ship segments, for example through collaboration with the CruiZE project.

Project participants

Management group

- Sintef Ocean
- NTNU
- Sintef Energy

Industrial reference group

- MMC First Process
- Ulmatec Pyro
- Selvåg Senior/Sørheim Holding
- Gasnor
- Øyangen
- Perfect temperature group
- Danfoss
- Isotherm Inc. (USA)

Scientific reference group

- International Institute of Refrigeration
- London South Bank University
- Johnson Controls Denmark

Project funding

- Norwegian research council ENERGIX
- Industrial partners are contributing with 20 % of total budget

Stay safe and healthy!